

Claims:

1. A method of enhancing two-dimensional contrast and range images rendered from three-dimensional streak tube imaging lidar (STIL) data that is generated by a STIL camera system, comprising the steps of:

providing rendered contrast image data and rendered range image data, wherein each of said rendered contrast image data and said rendered range image data comprise pixels of data that comprise an image;

scaling an intensity value associated with each pixel of data in said rendered contrast image data based on a mean intensity value of all pixels of data in said rendered contrast image data, wherein first interim contrast image data is created;

re-scaling said first interim contrast image data to a predetermined dynamic range, wherein second interim contrast image data is created;

modifying said second interim contrast image data to compensate for jitter and charge coupled device (CCD) array effects associated with the STIL camera system, wherein third interim contrast image data is created;

re-scaling said third interim contrast image data to said predetermined dynamic range, wherein fourth interim contrast image data is created;

24 normalizing said fourth interim contrast image data
25 using an exponential decay function that describes contrast
26 intensity roll-off associated with said fourth interim
27 contrast image data, wherein fifth interim contrast image
28 data is created;

29 modifying said rendered range image data to compensate
30 for jitter effects associated with the STIL camera system,
31 wherein first interim range image data is created;

32 modifying portions of said first interim range data
33 indicative of background in an image formed by said first
34 interim range data to compensate for CCD array effects and
35 range intensity roll-off associated with the STIL camera
36 system, wherein second interim range image data is created;

37 applying a noise reduction routine to said second
38 interim range image data to assign a revised intensity value
39 to pixels of data from said second interim range image data
40 failing noise criteria defined by said noise reduction
41 routine, wherein third interim range image data is created;
42 and

43 applying a histogram clip routine to said fifth interim
44 contrast image data and said third interim range image data,
45 wherein enhanced contrast image data and enhanced range image
46 data, respectively, are created.

1 2. A method according to claim 1 wherein said step of
2 scaling comprises the step of applying a \log_{10} scaling
3 routine to each pixel of data in said rendered contrast image
4 data.

1 3. A method according to claim 1 wherein each said step of
2 re-scaling comprises a linear operation.

1 4. A method according to claim 1 wherein said step of
2 modifying said second interim contrast image data comprises
3 the steps of:

4 generating a column profile from said second interim
5 contrast image data, said column profile defined as an array
6 of values with each one thereof being an average intensity
7 taken along a column of pixels of data from said second
8 interim contrast image data;

9 normalizing said second interim contrast image data
10 using said column profile, wherein normalized image data is
11 created;

12 generating a row profile from said normalized image
13 data, said row profile defined as an array of values with
14 each one thereof being an average intensity taken along a row
15 of pixels of data from said normalized image data;

16 applying a first smoothing routine to said row profile,

17 wherein a smoothed row profile is created;
18 generating smoothed image data by multiplying said
19 normalized image data by said smoothed row profile and then
20 dividing by said row profile;
21 un-normalizing said smoothed image data using said
22 column profile, wherein un-normalized image data is created;
23 applying a second smoothing routine to said column
24 profile, wherein a smoothed column profile is created; and
25 generating said third interim contrast image data by
26 multiplying said un-normalized image data by said smoothed
27 column profile and then dividing by said column profile.

1 5. A method according to claim 1 wherein said step of
2 modifying said rendered range image data comprises the steps
3 of:

4 generating a column profile from said rendered range
5 image data, said column profile defined as an array of values
6 with each one thereof being an average intensity taken along
7 a column of pixels of data from said rendered range image
8 data;

9 normalizing said rendered range image data using said
10 column profile, wherein normalized image data is created;

11 generating a row profile from said normalized image
12 data, said row profile defined as an array of values with

13 each one thereof being an average intensity taken along a row
14 of pixels of data from said normalized image data;

15 applying a smoothing routine to said row profile,
16 wherein a smoothed row profile is created;

17 generating smoothed image data by adding said
18 normalized image data and said smoothed row profile to form a
19 sum, and then subtracting said row profile from said sum; and

20 un-normalizing said smoothed image data using said
21 column profile, wherein said first interim range image data
22 is created.

1 6. A method according to claim 5 wherein said step of
2 modifying portions of said first interim range data comprises
3 the steps of:

4 selecting pixels from said smoothed image data that
5 satisfy a predetermined intensity criteria indicative of said
6 background, wherein said pixels so-selected define a
7 background mask;

8 generating a modified column profile from said smoothed
9 image data using said background mask, wherein only pixels in
10 said smoothed image data identified by said background mask
11 are used to generate said modified column profile; and

12 normalizing said smoothed image data using said
13 modified column profile, wherein said second interim range

14 data is created.

1 7. A method according to claim 1 wherein said noise
2 reduction routine is a salt and pepper noise reduction
3 routine.

1 8. A method according to claim 1 wherein said histogram clip
2 routine is an adaptive scheme that adjusts, for said fifth
3 interim contrast image data, clipping thresholds based on
4 pixel intensity distribution of said fifth interim contrast
5 image data, and that adjusts, for said third interim range
6 image data, clipping thresholds based on pixel intensity
7 distribution of said third interim range image data.

1 9. A method of enhancing two-dimensional contrast and range
2 images rendered from three-dimensional streak tube imaging
3 lidar (STIL) data that is generated by a STIL camera system
4 that utilizes left and right cameras to generate the STIL
5 data, comprising the steps of:

6 providing rendered contrast image data and rendered
7 range image data generated from the STIL data, wherein each
8 of said rendered contrast image data and said rendered range
9 image data comprise pixels of data that comprise an image;

10 adjusting each of said rendered contrast image data and
11 said rendered range image data to account for (i) missing
12 columns of pixels of data due to defects in the left and
13 right cameras, and (ii) differences in image background
14 intensity between images generated by the left and right
15 cameras due to differences between the left and right
16 cameras, wherein equalized contrast image data and equalized
17 range image data, respectively, are created;

18 scaling an intensity value associated with each pixel
19 of data in said equalized contrast image data based on a mean
20 intensity value of all pixels of data in said equalized
21 contrast image data, wherein first interim contrast image
22 data is created;

23 re-scaling said first interim contrast image data to a
24 predetermined dynamic range, wherein second interim contrast

25 image data is created;

26 modifying said second interim contrast image data to
27 compensate for jitter and charge coupled device (CCD) array
28 effects associated with the STIL camera system, wherein third
29 interim contrast image data is created;

30 re-scaling said third interim contrast image data to
31 said predetermined dynamic range, wherein fourth interim
32 contrast image data is created;

33 normalizing said fourth interim contrast image data
34 using an exponential decay function that describes contrast
35 intensity roll-off associated with said fourth interim
36 contrast image data, wherein fifth interim contrast image
37 data is created;

38 modifying said equalized range image data to compensate
39 for jitter effects associated with the STIL camera system,
40 wherein first interim range image data is created;

41 modifying portions of said first interim range data
42 indicative of background in an image formed by said first
43 interim range data to compensate for CCD array effects and
44 range intensity roll-off associated with the STIL camera
45 system, wherein second interim range image data is created;

46 applying a noise reduction routine to said second
47 interim range image data to assign a revised intensity value
48 to pixels of data from said second interim range image data

49 failing noise criteria defined by said noise reduction
50 routine, wherein third interim range image data is created;
51 applying a histogram clip routine to said fifth interim
52 contrast image data and said third interim range image data,
53 wherein enhanced contrast image data and enhanced range image
54 data, respectively, are created; and
55 applying an overlap correction routine to each of said
56 enhanced contrast image data and said enhanced range image
57 data to eliminate columns of pixels of data indicative of an
58 overlapping field-of-view between the left and right cameras.

1 10. A method according to claim 9 wherein said step of
2 scaling comprises the step of applying a \log_{10} scaling
3 routine to each pixel of data in said rendered contrast image
4 data.

1 11. A method according to claim 9 wherein each said step of
2 re-scaling comprises a linear operation.

1 12. A method according to claim 9 wherein said step of
2 modifying said second interim contrast image data comprises
3 the steps of:
4 generating a column profile from said second interim
5 contrast image data, said column profile defined as an array

6 of values with each one thereof being an average intensity
7 taken along a column of pixels of data from said second
8 interim contrast image data;

9 normalizing said second interim contrast image data
10 using said column profile, wherein normalized image data is
11 created;

12 generating a row profile from said normalized image
13 data, said row profile defined as an array of values with
14 each one thereof being an average intensity taken along a row
15 of pixels of data from said normalized image data;

16 applying a first smoothing routine to said row profile,
17 wherein a smoothed row profile is created;

18 generating smoothed image data by multiplying said
19 normalized image data by said smoothed row profile and then
20 dividing by said row profile;

21 un-normalizing said smoothed image data using said
22 column profile, wherein un-normalized image data is created;

23 applying a second smoothing routine to said column
24 profile, wherein a smoothed column profile is created; and

25 generating said third interim contrast image data by
26 multiplying said un-normalized image data by said smoothed
27 column profile and then dividing by said column profile.

1 13. A method according to claim 9 wherein said step of

2 modifying said equalized range image data comprises the steps
3 of:

4 generating a column profile from said equalized range
5 image data, said column profile defined as an array of values
6 with each one thereof being an average intensity taken along
7 a column of pixels of data from said equalized range image
8 data;

9 normalizing said equalized range image data using said
10 column profile, wherein normalized image data is created;

11 generating a row profile from said normalized image
12 data, said row profile defined as an array of values with
13 each one thereof being an average intensity taken along a row
14 of pixels of data from said normalized image data;

15 applying a smoothing routine to said row profile,
16 wherein a smoothed row profile is created;

17 generating smoothed image data by adding said
18 normalized image data and said smoothed row profile to form a
19 sum, and then subtracting said row profile from said sum; and

20 un-normalizing said smoothed image data using said
21 column profile, wherein said first interim range image data
22 is created.

1 14. A method according to claim 13 wherein said step of
2 modifying portions of said first interim range data comprises

3 the steps of:

4 selecting pixels from said smoothed image data that
5 satisfy a predetermined intensity criteria indicative of said
6 background, wherein said pixels so-selected define a
7 background mask;

8 generating a modified column profile from said smoothed
9 image data using said background mask, wherein only pixels in
10 said smoothed image data identified by said background mask
11 are used to generate said modified column profile; and

12 normalizing said smoothed image data using said
13 modified column profile, wherein said second interim range
14 data is created.

1 15. A method according to claim 9 wherein said noise
2 reduction routine is a salt and pepper noise reduction
3 routine.

1 16. A method according to claim 9 wherein said histogram
2 clip routine is an adaptive scheme that adjusts, for said
3 fifth interim contrast image data, clipping thresholds based
4 on pixel intensity distribution of said fifth interim
5 contrast image data, and that adjusts, for said third interim
6 range image data, clipping thresholds based on pixel
7 intensity distribution of said third interim range image

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8 data.